

NASA's Asteroid Redirect Mission: A Robotic Boulder Capture Option for Science, Human Exploration, Resource Utilization, and Planetary Defense

P. Abell¹, J. Nuth², D. Mazanek³, R. Merrill³, D. Reeves³, and B. Naasz²

¹NASA Johnson Space Center

²NASA Goddard Spaceflight Center

³NASA Langley Research Center

Background: NASA is examining two options for the Asteroid Redirect Mission (ARM), which will return asteroid material to a Lunar Distant Retrograde Orbit (LDRO) using a robotic solar electric propulsion spacecraft, called the Asteroid Redirect Vehicle (ARV). Once the ARV places the asteroid material into the LDRO, a piloted mission will rendezvous and dock with the ARV. After docking, astronauts will conduct two extravehicular activities (EVAs) to inspect and sample the asteroid material before returning to Earth. One option involves capturing an entire small ($\sim 4 - 10$ m diameter) near-Earth asteroid (NEA) inside a large inflatable bag. However, NASA is also examining another option that entails retrieving a boulder ($\sim 1 - 5$ m) via robotic manipulators from the surface of a larger ($\sim 100+$ m) pre-characterized NEA. The Robotic Boulder Capture (RBC) option can leverage robotic mission data to help ensure success by targeting previously (or soon to be) well-characterized NEAs. For example, the data from the Japan Aerospace Exploration Agency's (JAXA) Hayabusa mission has been utilized to develop detailed mission designs that assess options and risks associated with proximity and surface operations. Hayabusa's target NEA, Itokawa, has been identified as a valid target and is known to possess hundreds of appropriately sized boulders on its surface. Further robotic characterization of additional NEAs (e.g., Bennu and 1999 JU₃) by NASA's OSIRIS REx and JAXA's Hayabusa 2 missions is planned to begin in 2018. This ARM option reduces mission risk and provides increased benefits for science, human exploration, resource utilization, and planetary defense.

Science: The RBC option is an extremely large sample-return mission with the prospect of bringing back many tons of well-characterized asteroid material to the Earth-Moon system. The candidate boulder from the target NEA can be selected based on inputs from the world-wide science community, ensuring that the most scientifically interesting boulder be returned for subsequent sampling. In addition, the material surrounding the boulder can be collected from the surface, thus providing geological contextual information and additional samples of NEA regolith. The robotic manipulators used for capturing the boulder will ensure some of the surface remains undisturbed and that the boulder will retain its structural integrity, which will preserve the context of any samples collected by the astronauts and ensure a high level of science return.

Human Exploration: Due to the coherent nature of the boulder that will be collected, entire encapsulation of the asteroid material is not required. This facilitates exploration and sample collection of the boulder by astronauts in a variety of ways. The total time for EVA during the crew portion of the mission is very limited. Current estimates are that each of the two EVAs will only last four hours. The RBC option will allow crew members to have good situational awareness of the work site and quickly identify sample sites of interest. In addition, the samples to be collected can be readily accessed without having to deal with removal of an encapsulation system, which adds extra complexity and risk for the astronauts during EVA.

Resource Utilization: One of the most crucial aspects for resource utilization is the identification and collection of appropriate materials (e.g., volatiles, organics, metals, etc.) that contain components of interest. Prior characterization of NEAs is required in order to increase the likelihood that appropriate materials will be returned. Ground-based observations of small (< 10 m) NEAs are challenging, but characterization efforts of larger targets have demonstrated that NEAs with volatiles and organics have been identified. Two potential targets for the RBC option (Bennu and 1999 JU₃) have been previously identified as potentially rich in resources, and both are already targets of currently planned robotic missions that will characterize their physical properties in great detail.

Planetary Defense: The RBC option involves interaction with a well-characterized potentially hazardous-sized NEA that would enable NASA to conduct one or more planetary defense demonstrations. The primary method would use the collected boulder to augment the mass of the ARV and perform an Enhanced Gravity Tractor (EGT) demonstration on the NEA. Additionally, other approaches could be demonstrated during the mission, such as Ion Beam Deflection (IBD) and/or observation of a Kinetic Impactor (KI). The relative effectiveness of a slow push-pull method such as the EGT or IBD could be directly compared and contrasted with the results of the more energetic KI method on the target NEA.

Conclusions: This boulder option for NASA's ARM can leverage knowledge of previously characterized NEAs from prior robotic missions, which provides more certainty of the target NEA's physical characteristics and reduces mission risk. This increases the return on investment for NASA's future activities with respect to science, human exploration, resource utilization, and planetary defense.